STATION PAPER NO. 61

MAY 1958

SILVICAL *Characteristics* OF...

JACK PINE

(*Pinus banksiana*)

Paul O. Rudolf

LAKE STATES FOREST EXPERIMENT STATION

M. B. Dickerman, Director

FOREST SERVICE

U.S. DEPARTMENT OF AGRICULTURE

THE SILVICAL REPORTS

During 1907 and the following several years the U. S. Forest Service issued a series of silvical leaflets which covered the broad characteristics of a considerable number of major timber species. Since then much new knowledge has accumulated--some of it published in a variety of sources. There is also a considerable store of unpublished silvical information in the files of the forest experiment stations, the forest schools, and some other agencies. To compile this information systematically and make it available to foresters generally, the Lake States Forest Experiment Station is preparing reports on 15 individual species. Similar reports are being prepared by the other Federal forest experiment stations. When completed, these individual species reports will provide the basis for a comprehensive manual of silvics for the important trees of the United States, to be published by the U. S. Forest Service.

This report is one of the series being prepared by the Lake States Station. A preliminary draft was reviewed by several members of our own Station staff and by a number of well qualified staff members of other forest experiment stations, colleges, and universities; Federal, State, and Provincial forestry organizations; and forest industry. Their comments helped the author to make this report more complete, more accurate, and more up to date. Especially helpful reviews were submitted by E. W. Littlefield, New York Conservation Department; Fred G. Wilson, Madison, Wis.; and I. C. M. Place, formerly with the Department of Forestry and Wildlife Management, University of Wisconsin, now with the Petawawa Forest Experiment Station, Ontario.

Every effort has been made to ensure the accuracy and completeness of the information concerning the silvical characteristics of each species consistent with a brief treatment of the subject. We shall appreciate it, however, if any errors or ommissions of important information are brought to our attention.

M. B. Dickerman

M. B. Dickerman, Director

Cover: Typical mature jack pines grown in a moderately well-stocked stand on an average site in northeastern Minnesota. Drawing represents needles and cones.

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SILVICAL CHARACTERISTICS OF JACK PINE

(Pinus banksiana Lamb.)

by

Paul O. Rudolf
Lake States Forest Experiment Station[1/]

Jack pine is a short-lived, small-to-medium coniferous forest tree native to northern New England, the Lake States, and across Canada to the foothills of the Rocky Mountains. It occurs farther north than any other American pine. Its scientific name honors the British naturalist, Sir Joseph Banks. This tree also is called scrub pine, gray pine, Banksian pine, black pine, and in Canada, princess pine, Hudson Bay pine, and cyprés (20, 28, 29, 75).[2/]

DISTRIBUTION

The northern boundary of the botanical range of jack pine extends west from Nova Scotia through central Quebec and Ontario, the northern part of Manitoba and Saskatchewan, and the southern part of the Northwest Territories. The southern boundary stretches west from central Maine through central Michigan, Wisconsin, and Minnesota, runs north to central Manitoba, and then directly west to British Columbia. It is also local in southeastern Minnesota, northern Illinois, northwestern Indiana, northern New York, Vermont, and New Hampshire (63, 75, 87, 95, 103) (fig. 1). In eastern Canada (where at the north it becomes a mere shrub) and on the borders of its range in the northeastern States, it usually grows in small, widely scattered colonies. It occurs sparsely on the isthmus connecting Nova Scotia to the mainland, but is virtually absent from the remainder of that province.[3/] It is more abundant in central Michigan, central Wisconsin, and on sand dunes at the south end of Lake Michigan. North and west of Lake Superior it is common and often grows to comparatively large size. It probably is most abundant and attains its greatest size and beauty

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1/ Maintained by the Forest Service, U. S. Department of Agriculture, at St. Paul 1, Minnesota, in cooperation with the University of Minnesota.

2/ Names and dates in parentheses refer to literature cited at the end of this report.

3/ Place, I. C. M., unpublished information in letter of 8/28/56 to Director, on file at Lake States Forest Experiment Station.

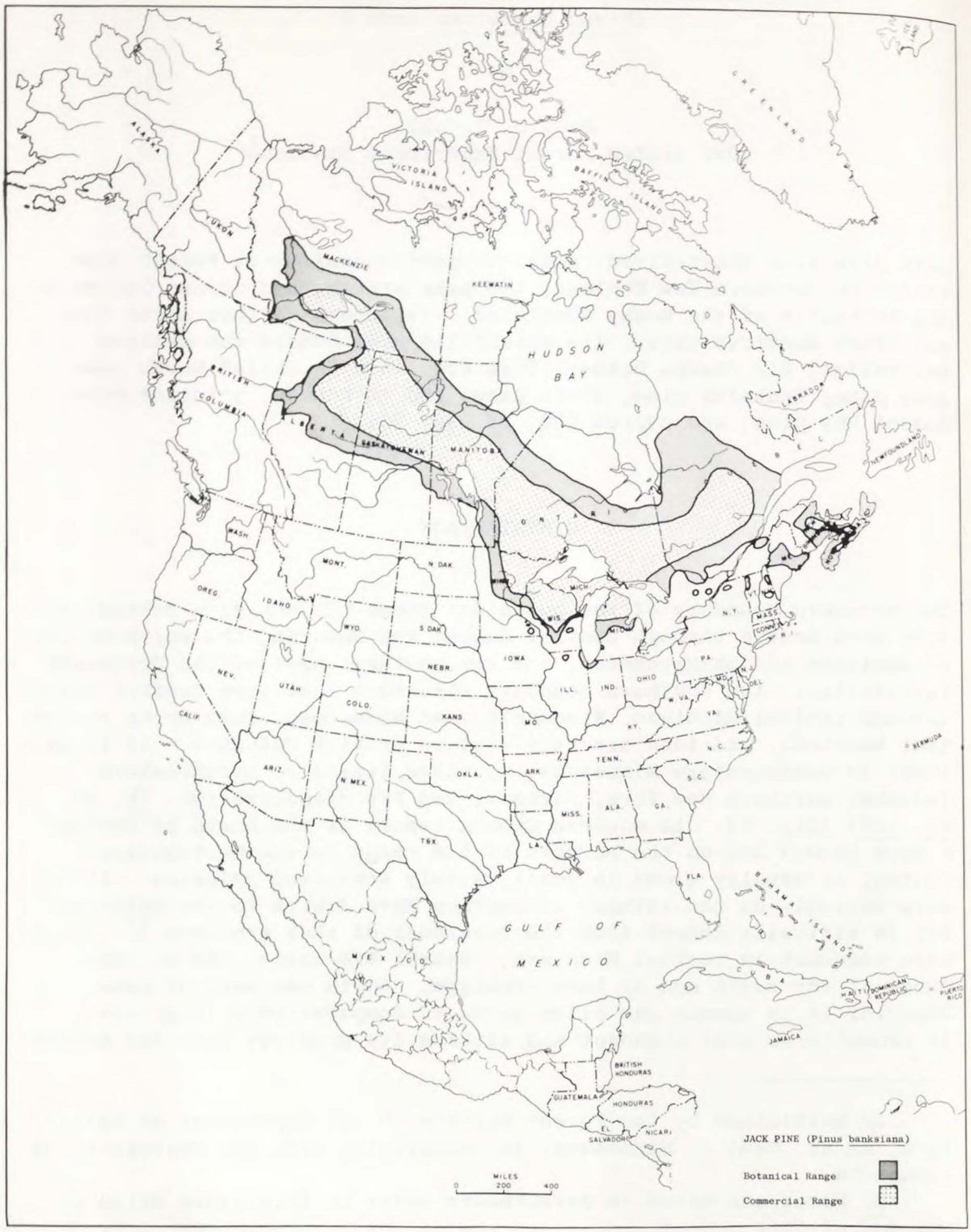

Figure 1.--Botanical and commercial range of jack pine.

west of Lake Winnipeg and north of the Saskatchewan River. It abounds in the valley of the Mackenzie River (28, 104).

The commercial range is confined to portions of the northern Lake States and adjacent Canada, where it extends both to the east and west (118) (fig. 1). Jack pine has been planted very little outside its natural range, but a slight extension of commercial range may arise from plantings on the sandhills of Nebraska and on strip-mined areas in the Central States and the Northeast.

HABITAT CONDITIONS

In general, jack pine grows in areas characterized by warm-to-cool summers, very cold winters, rather low rainfall, light sandy soils, and level to rolling topography. It occurs on burned areas where there is little severe plant competition and where the soil is acid and has very good drainage and aeration. Except for a small area on the south end of Lake Michigan (central forest region), it is confined to the boreal and northern forest regions. Although it occurs near the Coast in the northeast, jack pine grows chiefly in a continental climate.

Climatic Factors

Within the natural range of jack pine, the average January temperatures range from -20° to 25° F., and the average July temperatures from 55° to 72°. Average annual maximum temperatures range from 85° to 100°, and the highest temperatures ever observed are about 5° higher. Average annual minimum temperatures vary from -5° to -50°, and the lowest temperatures ever recorded are 10° to 20° lower.

Average annual precipitation ranges from 10 to 50 inches (but mostly between 15 and 35 inches). The average warm season (April to September, inclusive) precipitation varies from 6 to 25 inches. The average annual snowfall ranges from 30 to 200 inches (over much of the species range it varies from 40 to 100 inches). Summer droughts (periods of 30 or more days without measurable precipitation) occur commonly from the Lake States west.

The average date of the last killing frost in the spring ranges from April 30 to about July 1, and of the first killing frost in the fall from about August 10 to October 20. The frost-free period averages from 50 to 180 days (largely between 80 and 120 days).

In broad terms temperatures, rainfall, and frost-free periods increase from the northwestern toward the southeastern part of the range. The northern limit of jack pine closely parallels the 85° mean annual maximum temperature line, and in the west extends into the permafrost zone (22, 109, 125, 126). In some parts of its range, killing frosts may occur any month in the year (58).

Edaphic Factors

Natural stands of jack pine are confined largely to soils of the podzol region: melanized sands, podzolic sands, sandy podzols, and the gley-podzolic sands (142). Jack pine can maintain itself on very dry sandy or gravelly soils where other species scarcely can survive, but it grows best on well-drained loamy sands where the midsummer water table is 4 to 6 feet below the soil surface. Jack pine also occurs on dune sands and decomposed sandstone (in a nonglaciated area). It may invade muskegs (70 to 80 percent moisture content) during dry years, and also occurs over rock outcrops and on bald rock ridges (33, 35, 41, 43, 84). East of Hudson Bay it occurs on sandy burned heath lands; it avoids sedimentary bedrock and marine deposits of clayey soil (64). Jack pine does not occur naturally where the surface soil is alkaline, but it does grow on soils overlying limestone (8, 118). However, jack pine will grow satisfactorily on calcareous soils (pH 8.2) if normal mycorrhizae are present (38). Rather rarely jack pine grows on clay soils and here other species usually crowd it out (118). In southeastern New Brunswick, however, owing to a long fire history, jack pine occupies some thousands of acres of clayey soils.[4/]

In typical mature jack pine stands in Saskatchewan, the soil consists of (A_0) a 0- to 1-inch layer of pine needles and partially decomposed organic matter, (A_{2-1}) 0 to 4 inches of pale-brown structureless sand with occasional small nutty structures, (A_{2-2}) yellow structureless sand from 4 to 13 inches, (B_1) brownish-yellow structureless sand with medium-size nutty structures from 13 to 19 inches, (B_2) yellowish, structureless sand with larger nutty structures from 19 to 37 inches, (C) yellowish, structureless sand with nutty and cloddy structures from 37 to 55 inches, and brownish-yellow, structureless to nutty-structure layer with some small pebbles (probably from underlying sandy till deposits) from 55 to 66 inches (21, 67).

Although its requirements have not been worked out in detail, jack pine makes reasonably good growth on soils (surface 7 inches) with a pH of 4.5 to 6.5, 6- to 30-percent silt-plus-clay content, 0.01- to

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4/ Place: See footnote 3, page 1.

0.07-percent total nitrogen, a base exchange capacity of 8 to 11 m.e. per 100 grams, exchangeable calcium of 5 to 6 m.e. per 100 grams, exchangeable magnesium of 1 to 2 m.e. per 100 grams, available K_2O of 75 to 200 pounds per acre, and available P_2O_5 of 23 to 70 pounds per acre (8, 67, 68, 101, 116, 142). The thiamin and niacin requirements of seedlings appear to be met under average soil nutrient conditions (18).

The weight of dry organic matter returned to the soil annually by jack pine stands is similar to that for other species growing in the same general environment (78). The 12-month average for a jack pine forest in northeastern Minnesota was about 2,300 to 2,800 pounds per acre, ovendry weight (10, 57). The quantity of nutrient elements, expressed in percentage of dry weight, in freshly fallen jack pine litter averages as follows: Calcium, 0.61; potassium, 0.16; phosphorus, 0.04; nitrogen, 0.58; and ash, 4.15 (78). The litter is quite acid; pH 3.8 to 4.3 has been reported (7, 86). The total weight of the forest floor (unincorporated organic matter) under mature jack pine stands in north central Minnesota ranged from 33,000 to 42,000 pounds of ovendry matter per acre (9).

Physiographic Conditions

Where it is most abundant in the Lake States and Canada, jack pine grows most commonly on level to gently rolling sand plains, usually of glacial outwash, fluvial, or lacustrine origin. It also occurs less commonly on eskers, sand dunes, rock outcrops, and bald rock ridges (35, 43, 91). In northwestern Canada it may also grow on morainic hills (90). In southeastern Minnesota outliers occur on fairly steep valley slopes (95). In the Lake States jack pine is found chiefly at elevations between 1,000 and 1,500 (maximum of about 2,000) feet above sea level. In the East jack pine occurs on a variety of sandy sites from near the seashore up into the Adirondack Mountains. Elevations range from a few feet to about 2,000 feet above sea level, with the New Hampshire outlier at 2,500 feet (63).

Biotic Factors

In the northern Lake States and parts of central and western Canada jack pine grows in extensive pure stands. Frequently, however, it occurs in mixture with, and is predominant over, one or more associate species. It is a component of the following cover types recognized by the Society of American Foresters:

In the boreal forest region--jack pine, type 1; jack pine-paper birch, type 3; white spruce-balsam fir, type 4; jack pine-black spruce, type 6; jack pine-aspen, type 8; black spruce-aspen, type 10; black spruce, type 12; In the northern forest region--jack pine, type 1; northern pin oak, type 14; red pine, type 15; and white spruce-balsam fir-paper birch, type 36 (113).

In the boreal forest region the most common associates of jack pine are quaking aspen (Populus tremuloides), paper birch (Betula papyrifera), and sometimes black spruce (Picea mariana) with occasional white spruce (P. glauca) (90, 91, 113). In the northern forest region the most common associates are red pine (Pinus resinosa), northern pin oak (Quercus ellipsoidalis), quaking aspen, bigtooth aspen (Populus grandidentata), paper birch, black spruce, and white spruce. The aspens and paper birch (and sometimes red pine) usually are coordinate, the other species subordinate, in the mixtures (41, 113). Less frequent associates include eastern white pine (Pinus strobus), balsam fir (Abies balsamea), red maple (Acer rubrum), red oak (Quercus rubra), white oak (Q. alba), and, rarely in the Northeast, pitch pine (Pinus rigida) (76).

A large number of shrubs and herbs grow with jack pine. In Saskatchewan the poorest jack pine sites are largely free of shrubs; average sites are characterized by cowberry (Vaccinium vitis-idaea), bearberry (Arctostaphylos uva-ursi), and myrtle lowbush blueberry (Vaccinium angustifolium var. myrtilloides); the best sites have a shrub layer chiefly of green alders (Alnus crispa and A. c. var. mollis) with some redosier dogwood (Cornus stolonifera), roses (Rosa spp.), ribes (Ribes spp.), and limber honeysuckle (Lonicera dioica) (67). In the Lake States many of the same species occur along with Canada blueberry (Vaccinium canadense), lowbush blueberry (V. angustifolium), sweetfern (Comptonia peregrina), Jerseytea ceanothus (Ceanothus americanus), sand cherries (Prunus pumila and P. susquehanae), dwarf bushhoneysuckle (Diervilla lonicera), and, on the better sites, American hazel (Corylus americana) and beaked hazel (C. cornuta) (33, 58, 68, 95). Average brush density in northern Minnesota increases from about 1,000 stems per acre on the poorest sites to 10,000 or more on the best sites (23). Most typical nonwoody associates include reindeer mosses (Cladonia rangiferina, C. sylvatica, C. alpestris, C. crispata) and other lichens on poorer sites, and on somewhat better sites eastern bracken fern (Pteridium latiusculum), checkerberry wintergreen (Gaultheria procumbens), Canada beadruby (Maianthemum canadense), trailing-arbutus (Epigaea repens), bunchberry dogwood (Cornus canadensis), and such mosses as Caliergonella schreberi, Polytrichum juniperinum, Hylocomium splendens, and Hypnum crista-castrensis (16, 31, 39, 58, 64, 65, 67, 84, 106). A study in Lower Michigan indicated that 95 percent of the plants common in the jack pine plains are perennials with deep roots or rootstocks adapted to severe conditions of drought or of surface burning (39).

A number of birds and mammals common to the boreal and northern forest regions are associated with jack pine. These animals, however, occur neither constantly nor exclusively with jack pine, but are associated with the many other species and forest cover types in those regions. The animals that directly affect the survival, growth, or development of jack pine are discussed in the following sections.

LIFE HISTORY

Within its natural range and on the sites to which it naturally is adapted, jack pine follows a characteristic pattern of reproduction, growth, and development. Not only its inherent characters but also many environmental factors influence this pattern. Typically it is a very intolerant, drought-hardy, pioneer species occurring largely in even-aged stands on burned areas.

Seeding Habits

Flowering and Fruiting

Jack pine usually flowers in May to June (flowers of both sexes occurring separately on the same tree), the cones ripen in September of the second year, and seedfall usually begins that fall and may occur intermittently for several years (127). East of Hudson Bay, flowering has been observed in July (64). Over much of its range, jack pine has serotinous cones, some of which may remain closed for 10 to 25 years or longer. Frequently they do not open until a fire or logging occurs (33, 41). Ordinarily, however, some cones open every year. Some cones become overgrown with wood and still retain some viable seed (59). Over a 7-year period in northern Lower Michigan, flowering took place about mid-May, seeds began to ripen in late August, and dispersal of the new crop began about a month later and continued intermittently for several years. From year to year soundness of the naturally dispersed seed varied from 24 to 72 percent, the greatest soundness usually occurring during years of best seed production.[5/] Along the southern edge of its range jack pines bear nonserotinous cones which open promptly upon ripening and disperse their seeds during September or October.[5/]

5/ Unpublished information, Lake States Forest Experiment Station.

In the Lake States the small conelet first becomes visible in late May and pollination occurs shortly thereafter. By late July or August, when the conelet is 4 to 6 mm. long, it ceases to grow for the season.[5/] Actual fertilization, as in other pines, probably does not take place until the second summer, or about 1 year after pollination. At that time the cone is 35 to 40 mm. long (98, 117). The cones turn from green to yellowish-brown, to brown, to grayish-brown as they ripen (98). A high proportion of the seeds are viable when at least half the cone is brownish (98). Mature cones older than 1 year become gray. Some cones fall every year, but in the northern portions of the range many of them remain on the tree 20 years or longer, some actually becoming embedded in the wood (59, 137).

Seed Production and Dissemination

Under favorable growth conditions, jack pines have been known to produce both staminate and ovulate flowers at 3 years of age (94). Normally seed production begins at 5 to 10 years in open-grown trees and 10 to 25 years in stands (41, 118, 127). It is best at ages between 40 and 50 years. Thereafter it declines but continues almost until death, usually after 80 years (127). Viable seed has been obtained from newly produced cones of trees 185 years old.[5/]

Good seed crops are produced at intervals of 3 to 4 years, with light crops in most intervening years (127). Crop failures are very rare. Where serotinous cones are common, a good seed supply is available every year and at any time of the year. The seeds retained in the cones maintain high viability for at least 5 years and sometimes for more than 15 years (43). Even in the far north cone production may be reasonably good (64).

Only the 65 to 75 percent of the cone scales at the tip end bear fully developed seeds (117). In cones having an average of 73 scales, 50 seeds were formed, 40 of which were fully developed (117). On the average, normal cones contain 10 to 50 fully developed seeds (41, 107, 118). In one Minnesota study the typical curved jack pine cones contained less seed (average 21) than straight cones (average 46) (107). A well-developed, vigorous tree may produce from 1,000 to 1,200 cones in a year, although 300 to 500 probably is more common (41, 118). In well-stocked stands in northern Minnesota the trees held an average of 13 pounds or about 2,000,000 cleaned seeds per acre in unopened cones (42). Well-stocked, mature stands in the Lake States dispersed an average of 2,700 to 10,500 sound seeds per acre per year over 5 years, much of the total crop remaining in the unopened cones (43).

5/ Unpublished information, Lake States Forest Experiment Station.

Dewinged and commercially cleaned seed averages about 131,000 per pound (range 71,000 to 250,000) with a soundness of 94 percent (127).

Jack pine cones open best during dry weather when the temperature is at least 80° F. (77), although many of them remain closed until they are exposed to fire or until the branches are subjected to higher temperatures near the ground after wind breakage or logging (fig. 2) (41, 43). Over most of its range, where serotinous cones are common, up to 50 percent may open on the sunny part of the crown (117). Conversely cones sometimes open in very cold winters when the temperature is -50° or colder (144). In the Lake States seed may be disseminated any season of the year (43). The scales of serotinous jack pine cones are bonded by a resin which softens enough to permit scale separation at a temperature of about 116°; the petroleum ether extract of the bonding material has a melting point of 122° (25). It seems probable that the resin softens at a lower temperature in the nonserotinous strains in the southern parts of the Lake States. The cones are quite resistant to fire (77).

The effective range of seed dissemination, as measured by established seedlings, is about two tree heights, although it is low beyond one tree height (133).

Figure 2.--Cones from a freshly felled jack pine after 2 summer months' exposure at various heights above the ground; cone-opening is greatest at the warmest level near the soil surface and decreases regularly at the higher, cooler levels.

Factors Limiting Seed Production

Several agents act to reduce jack pine seed crops:

1. Prolonged rainy weather at the time of pollination may seriously diminish seed set (127).

2. Red squirrels (Tamiasciurus hudsonicus) cut cone-bearing branch tips and eat the seeds of some cones (30, 136).

3. Suppressed and low-vigor trees produce many staminate flowers but few cones (61).

4. Unidentified cone insects reduce seed yields in about 7 percent of the cones (117).

5. Trees infected with the oak-pine rust (Cronartium quercuum) produce smaller cones with more aborted sporophylls and seed about 20 percent lower in viability than normal (140).

6. Birds such as the bronzed grackle (Quiscalus quiscula), the rusty blackbird (Euphagus carolinus), the eastern robin (Turdus migratorius), the goldfinch (Spinus tristis), the eastern chipping sparrow (Spizella passerina), and the slate-colored junco (Junco hyemalis) may consume large quantities of seed (43, 136).

7. Such rodents as the least chipmunk (Eutamias minimus), white-footed mouse (Peromyscus spp.), red-backed vole (Clethrionomys gapperi), and red squirrel also may consume up to 75 percent of the seed dispersed (43, 136).

Vegetative Reproduction

In nature jack pine does not reproduce vegetatively. Scions from 10- to 20-year-old jack pines have been grafted successfully on to potted understocks of jack pine, red pine, Scotch pine (Pinus sylvestris), and Japanese red pine (Pinus densiflora) in the greenhouse.[6/] Red pine and Scotch pine scions have also been grafted on to jack pine understocks.[6/]

6/ Hitt, R. G., unpublished information in letter of 9/17/56 to Director, on file at Lake States Forest Experiment Station.

Seedling Development

Establishment

Jack pine seed occasionally exhibits some dormancy, but usually germinates to capacity (average 68 percent) within 15 to 60 days under favorable conditions (127). Scorched seed from burned trees has germinated within 4 days of sowing under favorable conditions.[7/] Where moisture is adequate, germination takes place when air temperature maxima reach 64° F. (134). Seeds falling in April, May, June, and November establish seedlings better (19 to 28 percent) than those falling in July to October (1 to 14 percent) in northeastern Minnesota (135).

Jack pine seed germinates best on mineral soil (77). In northeastern Minnesota, germination under clear-cut and partially cut jack pine stands averaged 60 percent on mineral soil, 49 percent on burned duff, 47 percent on scarified and shaded duff, and 17 percent on undisturbed duff (74). Germination is nearly as good on humus that is ground up or artificially moistened as on mineral soil (45). Partial shade is beneficial to jack pine seed germination (46). Survival on the various soil surfaces shows the same trends as germination (12). On the average, the chance that a seed will germinate and the seedling survive 2 years is 9 to 12 times as great on mineral soil as on undisturbed soil in the Lake States (42, 74). Highest survival follows early spring germination (43). Germination is better on fine sands than on coarse sands (47). Germination may begin within 8 days after seeding (47). Mortality begins within a few days after first germination and usually is heaviest during the first 3 months. Thereafter losses normally are small (74).

Seedling establishment generally is best where there is some shade (as along the edges of stands) and where soil moisture is reasonably abundant (117). During a drought year (53 percent normal summer precipitation) in the Lake States, 1-year-old jack pine seedlings survived 77 percent where the permanent water table was within 5 to 6 feet of the soil surface (2 to 5 percent available moisture) and only 29 percent where the water table was below 6 feet (1 to 3 percent available moisture) (131). The percent of viable seed producing 2-year-old seedlings was 7.7 on the high water table and only 0.9 on the low (121). Under similar circumstances 1- and 2-year-old seedlings survived 29 to 33 percent and grew 1 to 2 inches in the open as compared to 62 to 77 percent survival and 2 to 5 inches growth under aspen giving 56 percent of full sunlight at 4 inches above the ground (132).

7/ Ahlgren, C. E., unpublished 1956 data in letter on file at Lake States Forest Experiment Station.

One- to two-year-old seedlings grown under a nitrogen supply above the optimum (which was 200 to 250 p.p.m.) are less drought resistant than those grown at the optimum or less; probably most soils in the field are below this optimum (19).

Most of the older jack pine stands appear to have been established following fires, but many younger stands in the Lake States have developed from advance reproduction under an overstory that was clearcut.[8/] Unless conditions for germination and early survival are favorable, however, good regeneration does not necessarily follow burns (43, 115).

With the onset of cold weather in the fall the foliage of young jack pine seedlings often changes from green to brownish-purple (44).

Young jack pine seedlings can grow in light as low as 2.38 percent of full sunlight (15). However, more light is required for establishment. For example, in northern Minnesota the number of established jack pine seedlings per acre by crown density of overstory was as follows: 1,690 at 0.1, 1,116 at 0.2, 730 at 0.3, 180 at 0.4, 40 at 0.5, and 0 at 0.6 and higher (24). Under stands, jack pine seedlings are most frequent and abundant in light intensities of 11 to 30 percent of full sunlight, but height growth is greatest in light intensities of 52 percent or more (112).

Neither age of mother tree (10 to 80 years) nor age of cones (1 to 5+ years) from which seed originated affected the growth and development of jack pine progeny in Lower Michigan (88, 89, 102).

During the first season the root system penetrates to a depth of about 5 to 10 inches. By the end of the second growing season jack pine seedlings on typical sandy soils in the open have a dry weight of 1 to 2 grams and have developed 3- to 4-inch tops, and root systems 11 to 13 inches deep with a lateral spread of 18 to 24 inches (120).

On a moist sandy soil (water table about 30 inches below the surface) in Upper Michigan, roots penetrated to 1.8 feet in 2 years and went only to 2.0 feet by 7 years; the lateral spread, however, increased from 3.0-4.0 feet at 2 years to 14.0-16.2 feet at 7 years (40). For the 7-year trees the average volume of the top (stem, branches, and foliage) was about 4,000 cc. as compared to 1,200 cc. for the root system (40).

The following silvicultural methods have been recommended as favoring regeneration of jack pine in the northern Lake States: Clearcut mature

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8/ Fixmer, Frank, unpublished information attached to letter of 9/5/56 to Director, on file Lake States Forest Experiment Station.

stands, scarify the ground mechanically to expose at least 60 percent mineral soil, and scatter cone-bearing slash uniformly over the area (43, 144). These methods have proved more consistently successful than attempts to use fire as a silvicultural tool in regenerating jack pine stands in the Lake States. In the southern part of the region, where jack pine bears largely nonserotinous cones, adequate reproduction probably could be obtained by a two-cut shelterwood system applied before the stand has lost its vigor; if sod or undergrowth is heavy and advance reproduction has not been established, mechanical scarification should accompany the first cutting.[9/]

Early Growth

The time that shoot growth begins and ends varies within a locality and with climatic conditions over the range of jack pine. Over a period of 5 to 9 years in the Upper Peninsula of Michigan, shoot elongation began about May 10, leafing began about 1 week later, winter buds were formed about mid-July, and height growth ceased about September 5.[10/] Height growth, excluding elongation of the winter bud, was completed in an average of 64 days. In another locality it was 82 percent completed by the end of June and ceased at the end of July (68). If favorable moisture conditions prevail in late summer, jack pine frequently has a second period of shoot elongation and produces what are called "lammas shoots". The amount of shoot growth seems to be related to the abundance of rainfall during the previous growing season (1).

In northern Minnesota, root growth begins, usually within a week of the onset of shoot growth, when the temperature reaches 40° F. in the upper 6 inches of soil. Growth is better after the soil temperature reaches 50°. Root growth ceases in the fall when the soil temperature drops to 45° for 6 days or more. In some years root growth may begin in April and continue to late October. Seven-year-old trees growing under favorable conditions elongated their lateral roots an average of 15 inches (8 to 24 inches) in 1 year (68).

Jack pine grows moderately rapidly as a seedling: Average heights of wild seedlings are about 2 inches at 1 year, 6 inches at 2 years, and 1 to 3 feet at 4 years (118). Initial growth in plantations is more rapid. For several years thereafter annual height growth will average 1 to 1.5 feet on medium sites (50).

9/ Author's suggestion.

10/ Unpublished data, Lake States Forest Experiment Station.

Factors Limiting Seedling Development

A number of factors act to hinder germination and early survival:

1. Summer droughts and high surface soil temperatures frequently kill or injure young jack pine seedlings--exposure to temperature of 127° F. for 5 hours will kill 1-year-old jack pine seedlings in dry air (relative humidity 13 to 25 percent) (111). Lower temperatures and shorter exposures prove lethal under moister conditions (111). Drought losses are greatest among seedlings under 6 inches in height and among those grown without protective tree or shrub cover; except in very severe years seedlings over 4 feet tall suffer little loss (110).[10/] Under severe drought and heat conditions (soil surface temperatures up to 175°) jack pines $2\frac{1}{2}$ years from seed suffered heavy mortality--74 percent from heat and 26 percent from drought (130).

2. Low temperatures may cause heavy mortality, especially to succulent fall-germinated seedlings (43, 49, 144).

3. Insects (including a grasshopper (Camnula pellucida), caterpillars (Halisidota spp.), a sawfly (Empetria spp.), and the jack-pine budworm (Choristoneura pinus)) may destroy as many as 25 percent of the seedlings the first 2 years (74).

4. White grubs (larvae of the May beetles, Phyllophaga spp.) may cause considerable losses, especially in dry years (74, 120).

5. A weevil (Pissodes approximatus) that breeds in cut or damaged pine stumps or logs has killed young jack pine seedlings (48).

6. An insect, Retinodiplosis (possibly resinicola), kills seedlings in parts of western Canada (92).

7. The jack-pine shoot moth (Eucosma sonomana) may cause considerable damage to terminal shoots of young seedlings (108).

8. The competition of subordinate vegetation seriously hinders reproduction (112).

9. Post-emergent damping-off, mildew, and unidentified root rots cause some mortality during the first 2 years (74).

10. Frost heaving on loamy soils, birds, rodents, trampling by large animals, and smothering by litter also kill some young jack pine seedlings (74, 120).

10/ Unpublished data, Lake States Forest Experiment Station.

Although the establishment period is critical, many factors continue adversely to affect survival and growth of jack pine during the seedling stage:

1. Early spring fires may kill 90 percent or more of the seedlings under 7 feet in height (128).

2. Under very severe drought conditions in Lower Michigan mortality of seedlings up to 6 feet tall has been heavy on the coarser soils and moderate on slightly finer soils.10/

3. Seedlings under 7 feet tall have been killed, and larger trees have suffered serious reduction of height and diameter growth and impaired stem form as a result of deer (Odocoileus virginianus) browsing (5, 119). In Lower Michigan all seedlings in some stands have been injured by deer browsing (99). In central and northern Wisconsin 40 percent of the jack pine seedlings were heavily browsed by deer (124). If repeated frequently such injury may bring about mortality or permanent damage.

4. In central and northern Wisconsin snowshoe hares (Lepus americanus) nipped 5 to 10 percent of the jack pine reproduction and reduced height growth about 10 percent. In the Lake States and Canada these hares may girdle and kill 25 to 95 percent of the seedlings under 1.5 inches in diameter in dense stands--this sometimes provides a useful thinning (3, 4, 21, 37, 67, 71).

5. Several sawflies (Neodiprion lecontei, N. compar, N. nigroscutum, N. pratti banksianae, N. maurus, N. sertifer, N. swainei, and N. nanulus nanulus) often defoliate and sometimes kill seedlings up to 5 feet tall (36, 96).

6. The jack-pine budworm (Choristoneura pinus) defoliates seedlings growing beneath scattered mature stands (43).

7. The white-pine weevil (Pissodes strobi) attacks jack pine seedlings commonly and frequently in the Lake States, reducing height growth and impairing form (43).

8. The pitch nodule maker (Petrova albicapitana) often attacks jack pines up to about 15 to 25 feet tall; some shoot breakage results (67).

9. The pine root collar weevil (Hylobius radicis) girdles and kills occasional jack pine seedlings (36, 138).

10/ Unpublished data, Lake States Forest Experiment Station.

10. The pine chafer (Anomala oblivia) occasionally defoliates seedlings severely (43).

11. The pine tortoise scale (Toumeyella numismaticum) may be destructive to young stands (6, 43, 67).

12. The Saratoga spittlebug (Aphrophora saratogensis), alone or associated with burn blight (Chilonectria cucurbitula), has caused serious losses to planted jack pine stands in the Lake States (101).

13. A needle rust fungus (Coleosporum solidaginus) has caused some defoliation of seedlings (43).

14. The sweetfern blister rust (Cronartium comptoniae) sometimes causes considerable mortality in young seedlings and slightly reduces growth of some survivors (114).

Figure 3.--An excellent stand of jack pine with a slight admixture of red pine in northern Minnesota. (Photo courtesy Forestry Division, Minnesota Conservation Department.)

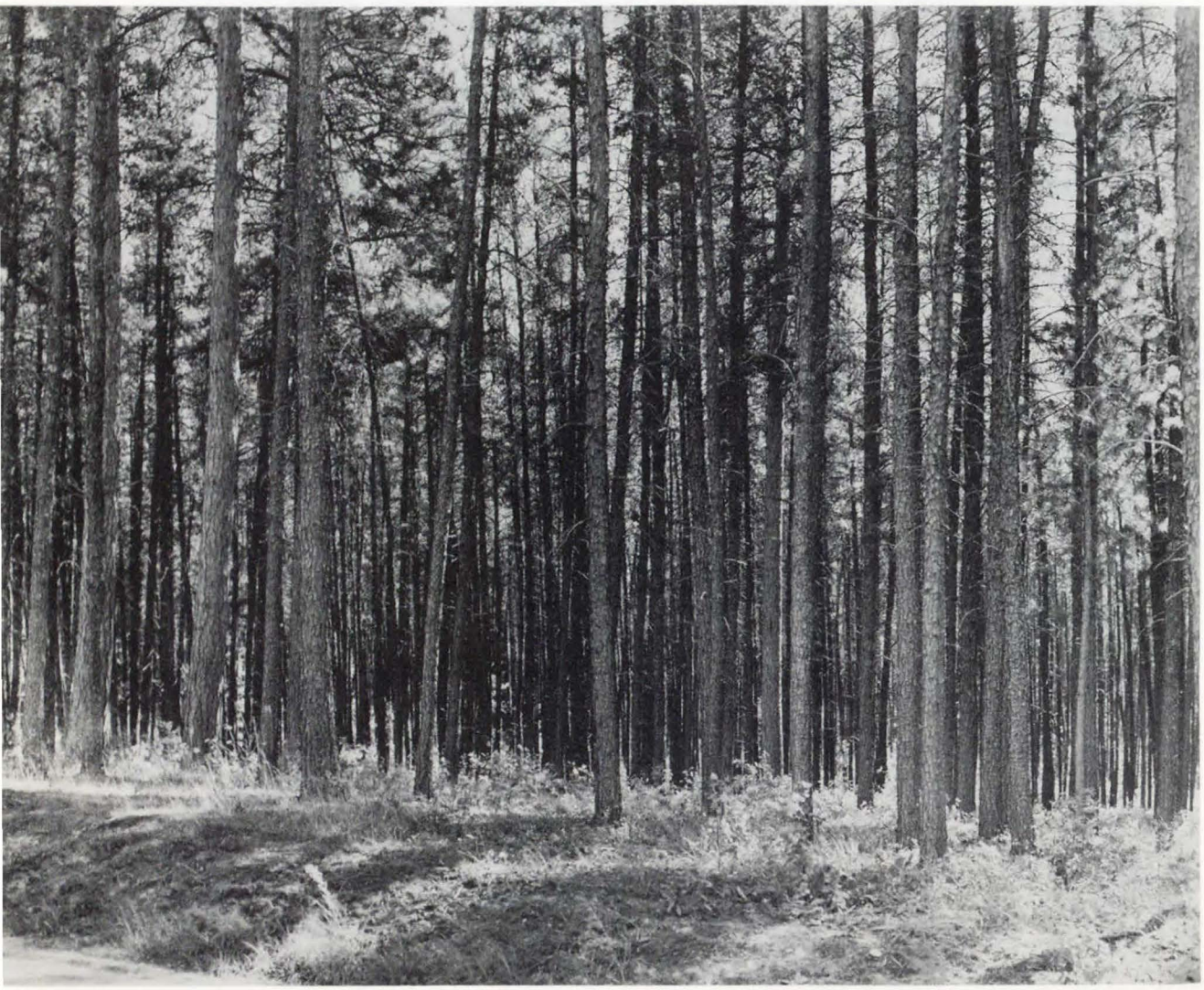

Figure 4.--A typical jack pine stand on an average sand plains site in northern Minnesota. (Photo courtesy Forestry Division, Minnesota Conservation Department.)

15. Much more prevalent is the oak-pine rust; it may infect 40 to 50 percent of young seedlings and cause considerable mortality from girdling and breakage at galls on the main stem.[10/]

Sapling Stage to Maturity

In well-stocked forest stands, jack pine develops into a short to medium-tall, rather slender tree with narrow rather open crown covering about 30 to 45 percent of the stem; in the open it develops a stocky stem, often of poor form, and a wide, spreading crown with branches long persistent (41) (figs. 3 and 4). Old trees in stands

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10/ Unpublished data, Lake States Forest Experiment Station.

have shorter, flatter crowns. The most vigorous dominants in a 65- to 70-year-old stand contained 91 pounds air-dry weight of foliage and branch tips, compared to 64 pounds for weaker dominants and codominants, and 46 pounds for intermediate and suppressed trees (79).

Frequently, but not invariably, jack pine develops a taproot as a seedling and maintains it to maturity (33, 118). On deep, well-drained soils the roots may penetrate below 9 feet (2, 51). Trees without distinct taproots usually have lateral roots which turn and grow vertically downward (often along old root channels) as they approach other trees (2, 32). The bulk of the root system, however, consists of laterals confined largely to the upper 18 inches of soil; much of the system is in the upper 6 inches (31, 32). A tree 45 feet tall, 10 inches d.b.h., growing in a stand of 0.5 density in northern Minnesota had a root system which penetrated 5.5 feet in depth and had a lateral spread of 16 to 28 feet (32). In a square yard of soil under a jack pine stand averaging 8 inches d.b.h. and 0.6 density, there were 33,829 inches of roots from 318 plants of 27 species (jack pine 11,304 inches; white spruce, 3,646; shrubs, about 8,000; and herbs, about 10,000) (31). There is a close relation between tree vigor (especially crown density) and root development. In northern Minnesota the most vigorous dominants in a 65- to 70-year-old stand had developed 31 pounds (air-dry weight) of roots, compared to 24 pounds for weaker dominants and codominants, and 15 pounds for intermediate and suppressed trees; the first group recovered best from drought and insect defoliation (79). Annual root growth in 25- to 28-year-old jack pines in northern Minnesota averaged 9 to 12 inches (2.5- to 27-inch range); it fell off when available soil moisture dropped below 4 percent (68). Because of its relatively deeper, more rigid root system, jack pine has been considered less able than white spruce to grow on the shallower soils above the permafrost in northern Canada (90). Nevertheless jack pine actually is more abundant than white spruce in the northern pre-Cambrian areas of Saskatchewan, where premafrost is quite common.[11/]

Growth Rates and Sizes Attained

Growth is most rapid in the juvenile stages; seedlings reach breast height in 5 to 8 years (67, 101). For the first 20 years of its life jack pine, in its native range, is the fastest growing conifer other than tamarack (Larix laricina) (33). For the first 50 years, height growth on average sites in Minnesota averages a little more than 1 foot

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11/ A. Kabzems, unpublished information in letter of 9/21/56 to Director, on file at Lake States Forest Experiment Station.

per year. Thereafter the rate drops about 0.2 foot per decade until 80 years after which it almost stops (43). On good sites the rate is faster and longer maintained; on poor sites the reverse is true. On typical sand plains sites, growth is about one site quality better where the water table is 4 to 6 feet from the soil surface than where it is deeper.[12/] Stands usually break down between 80 and 100 years; on the poorest sites after 60 years (33). Maximum ages known are from 180 to 200 years.[12/] Growth is somewhat slower but longer maintained in Canada (62, 67).

A study in Wisconsin in dense 26- to 35-year-old jack pine on low medium sites revealed a strong correlation of diameter growth rate with the percent of total height in the living crown: 5-year diameter growth for trees with 10, 20, 30, 40, and 65 percents of their total height in live crown was respectively, 0.07, 0.30, 0.52, 0.68, and 0.90 inches (122).

East of Hudson Bay 25-year-old trees measured were 18 to 21 feet tall, had a current annual height growth of 5 to 8 inches, and an annual radial growth of 0.1 to 0.2 inch in good years (64). In northwestern Alberta in two localities jack pine averaged 46 feet tall and 6 inches d.b.h. at 32 years and 80 feet tall and 12 inches d.b.h. at 65 years (84).

Normally, mature trees are about 55 to 65 feet tall, and 8 to 10 inches in diameter breast high, although trees have attained 100 feet in height and 25 inches in diameter (33, 97, 101).[12/] In the Lake States, well-stocked, unmanaged jack pines at 60 years (rotation age for poorer sites) attain the following dimensions and merchantable yields: (50, 133).

12/ Unpublished data, Lake States Forest Experiment Station.

Site class	Site index 1/	Average stand diameter	Average height dominants	Per acre			
				Total trees	Total basal area	Merchantable yield	
		Inches	Feet	Number	Sq. ft.	Cu. ft. 2/	Bd.-ft. 3/
Good	66	10.4	75	255	151	2,870	5,650
Medium	53	8.8	60	340	142	2,330	3,050
Poor	40	6.9	45	510	132	1,620	1,150
Very poor	30	5.1	33	70	10	4/ 100	30

1/ Average height of dominants at 50 years.

2/ Gross volume, excluding bark, of trees 5 inches and larger d.b.h., to a top diameter of 3 inches inside bark.

3/ Net volume, Scribner rule, of trees 9 inches and larger in d.b.h.; top diameters variable, minimum being 6 inches inside bark.

4/ Yields on these sites average about 700 cubic feet at 50 years, before serious retrogression begins.

Yields are somewhat greater at rotation age on the medium sites (70 years) and good sites (80 years). For pulpwood production, rotations of 50 years probably are better (43). Average merchantable cubic volumes per tree in fully stocked stands vary percentagewise about as follows in the Lake States: Good site, 100; medium site, 60; poor site, 29; and very poor site, 12 (50).

Rather comparable yields have been reported from Saskatchewan (67). Yields over the rotation ages can be increased up to 90 percent by management through harvesting potential mortality and placing the growth on the better trees.12/

Of course natural stands commonly are understocked, so average yields shown by the Forest Survey12/ are considerably less than those given above. Assuming a normal distribution of age classes, average yields and mean annual increments in the Lake States vary with intensity of management by sites as follows:12/

12/ Unpublished data, Lake States Forest Experiment Station.

Site class	Average yields[1] per acre		Average annual[1][2] increment per acre	
	Unmanaged	Intensive management	Unmanaged	Intensive management
	Cubic feet	Cubic feet	Cubic feet	Cubic feet
Good	515	782	23.1	50.0
Medium	378	570	18.3	38.3
Poor	250	375	13.0	27.0

1/ Gross volume, excluding bark, of trees 5 inches d.b.h. and larger to a top diameter of 4 inches inside bark.

2/ Mean annual increments cited are for entire rotation age (60 years).

Reaction to Competition

Jack pine is one of the most intolerant trees in the region where it is native (33, 41). Based on a scale which ranges from 10.0 for eastern hemlock (Tsuga canadensis) to 0.7 for the aspens, jack pine rates 1.8; this places it less tolerant than red pine (2.4) but more so than paper birch (1.0), tamarack (0.8), or the aspens (0.7) (54). Other classifications include jack pine in the lowest or next to the lowest of five tolerance classes (13, 145). The species may be relatively more tolerant in the early seedling stage (15). Beyond that stage, however, it can stand considerable crowding but little overhead shade (33).

Most natural jack pine stands are understocked, but at times dense sapling stands develop (10,000 to 40,000 or more per acre). Height growth may be only slightly depressed, but such stands may stagnate in diameter growth if not thinned reasonably early (55, 106). Jack pine is slow to thin itself naturally (43). Noncommercial thinnings promise the best return if done in seedling stands up to 10 feet in height. At that stage an expenditure of 1.2 man-days' labor per acre can be very effective (43). Thinnings done in large sapling and small pole stands with 1,500 to 5,000 stems per acre have resulted in good growth increases on the remaining trees. Commercial thinnings can begin in stands about 30 years old (43, 106). On better-than-average sites in northeastern Minnesota, reasonably good growth response (30 to 90 percent diameter increases) resulted even in stands 55 to 65 years old (129).

As is common in intolerant species, dominance is not well expressed in dense young stands. In fully stocked stands the percentage of trees in the dominant and codominant classes increases regularly from about 51 in stands with an average breast high diameter of 2 inches to 65 at 5 inches, and 81 at 9 inches (50). In Saskatchewan these percentages run 8 to 10 percent lower at given diameters (67). In stands of lower density the proportion of dominants will be higher. In jack pine stands desirably stocked for good growth the average spacing of trees bears a definite relation to the average height of the stand (143). The spacing in percent of average stand height between 10 and 80 years decreases from 21 to 18 on good sites, 27 to 20 on medium sites, and 30 to 20 (at age 60 and then up to 30 again) on poor sites (50).

In dense stands jack pine prunes itself moderately well, but where stocking is less it prunes itself very poorly (67).

Jack pine is a pioneer species on burns or other exposed sandy sites (41, 97). However, in the absence of fire or other catastrophes, jack pine tends to give way to other more tolerant species, except on the poorest, driest sites where it may long persist and form an edaphic climax (43, 67, 84, 91). On the better sandy soils (loamy sands or sandy loams) in northern Minnesota the usual succession is from jack pine to red pine, to eastern white pine, to a hardwood type composed of sugar maple (Acer saccharum), basswood (Tilia americana), and northern red oak (70). Sometimes the red pine and white pine stages are absent and jack pine is followed first by speckled alder (Alnus rugosa), American hazel, beaked hazel, paper birch, and quaking aspen; this in turn is followed by either the sugar maple-basswood association or spruce-fir, even though the soil may be too poor for the satisfactory growth of the latter (43). On loamy soils in northeastern Minnesota and parts of Canada, jack pine is succeeded by black spruce, white spruce, balsam fir, and paper birch (43). Eventually this probably would develop into a spruce-fir climax. Frequent fires in young stands in the Lake States may result in elimination of the jack pine and ascendancy of northern pin oak and scrubby specimens of other oaks. In parts of northwestern Canada, jack pine may be replaced directly by white spruce (84, 90). In parts of eastern Canada jack pine sometimes is succeeded by pure black spruce (64).

Limiting Factors in the Sapling to Mature Stages

Among the many enemies that cause damage or mortality to sapling and mature jack pines are the following:

1. A typical early spring surface fire on the jack pine plains of the Lake States has been observed to kill about 25 percent of the trees from 7 feet tall to 4 inches d.b.h. (128). Hot fires sometimes completely kill pole stands (14, 43). Trees not killed in fires often are butt-scarred or otherwise injured (67). Such scars are the principal avenue of entrance of wood-destroying fungi (139). Up to 60 percent of a mature stand may be injured by ground fires, although the trees usually are quite resistant (41, 117). At present in Saskatchewan fires annually destroy more jack pine volume (4.40 million cubic feet) than is utilized (4.23 million cubic feet) (67).

2. Except on shallow soils, jack pine generally suffers little windthrow before maturity, but losses may be heavy locally (41, 43). Wind breakage probably is a more common cause of damage (117).

3. Glaze storms, especially when followed by strong winds, may cause heavy local damage (43, 69).

4. Prolonged drought periods may reduce growth by 20 percent or more and sometimes cause mortality even in mature stands (43, 58).

5. Spindly trees in dense young stands often are injured by snow breakage and bending (33). To some extent this injury may accomplish a desirable thinning.

6. The jack-pine budworm may cause serious defoliation, especially on the poorer sites (52, 53, 67). In Lower Michigan budworm infestations for 2 successive years caused the death of 3 percent of the poles, 8 percent of 4-inch saplings, and 33 percent of 2-inch saplings (17). The budworm may also seriously reduce the crop of staminate flowers (60, 61).

7. Several sawflies (Neodiprion pratti banksianae, N. virginiana, N. swainei, and N. nanulus nanulus) have defoliated extensive areas of jack pine in Ontario and Quebec; in some stands height growth has been reduced 5 to 10 feet (16, 26).

8. An insect, Retinodiplosis (possibly resinicola), in western Canada kills some branch tips, often in association with attacks by the jack-pine budworm or the pitch nodule maker (92).

9. The pine chafer beetle sometimes weakens mature trees by defoliation (43).

10. Trees weakened by drought, storm, or other injuries sometimes are attacked by pine sawyer beetles (Monochamus spp.) and a bark beetle (Ips pini) (43).

11. On moist sites a weevil (Hypomolyx, probably piceus) injures roots on jack pines and causes some mortality in trees up to 40 years old (138).

12. Rots caused by Polyporus schweinitzii, Fomes pini, F. pinicola, and some other fungi also have been reported (140, 141).

13. In Canada westward from western Ontario a dwarf mistletoe or witches'-broom (Arceuthobium americanum) reduces the vigor of trees and is associated with considerable mortality; as many as 40 percent of the trees in a stand may be infected (27, 67).

14. Other disease organisms attacking sapling to mature jack pines include a spindle rust gall (Cronartium comandrae), a globose rust gall (C. harknessii), a needlecast (Hypodermella spp.), several needle rusts (Coleosporium spp.), the oak-pine rust, the sweetfern blister rust, the shoestring fungus (Armillarea mellea), and Fomes annosus (67, 141).

15. Porcupines (Erithizon dorsatum) have been observed to damage seriously more than 11 percent of the trees in stands; they prefer trees above 3 inches d.b.h. and especially the soft bark near the tops of large trees (41, 67, 100).

16. Frequently noticeable in the early spring is the death of twigs which were partially girdled when red squirrels cut cones the previous fall.[12/]

17. Spruce grouse (Canachites canadensis) sometimes consume large numbers of jack pine buds (80). Occasionally ruffed grouse (Bonasa umbellus) and more rarely the pine grosbeak (Pinicola enucleator) will debud jack pine.[13/] Sapsuckers (Sphyrapicus varius) girdle some trees.

SPECIAL FEATURES

In earlier years some of the larger jack pines were cut and marketed as sawlogs along with red pine. Jack pine was used but little prior to 1920, however. Now it is used chiefly for pulpwood, box lumber, and fuel. Less important uses include railway ties, mine timbers, slack cooperage, and poles and posts (20).

12/ Unpublished information, Lake States Forest Experiment Station.

13/ Wilson, F. G., unpublished information with letter of 9/3/56 to Director, on file at Lake States Forest Experiment Station.

Jack pine has been planted extensively in the Lake States for wood production; it has also been planted to some extent for dune and sand-blow control, Christmas tree production (locally), and windbreaks (101). The most extensive planting outside its native region has been on the Nebraska sandhills. Jack pine also has been used in planting strip-mined areas and some of the poorer sites in the Central and Northeastern States.

The oleoresin of jack pine yields about 21 percent turpentine consisting of dℓ- and dα-pinene 85 percent, and β-pinene 10 percent (81).

Jack pine is less resistant than its common conifer associates (red pine, white pine, black spruce, white spruce, and balsam fir) to damage from herbicides in the kinds and concentrations commonly used for control of weeds and hardwoods growing in association with it. Applications of 2 or more pounds of acid per acre of 2,4-D and 2,4,5-T in mixture may kill 6- to 12-inch-tall jack pine seedlings (56). Good control of overtopping aspen and brush in northern Minnesota and of oaks in Lower Michigan, however, has been obtained with both aerial and ground sprays of 1 to 2 pounds acid equivalent of phenoxyacetic acid herbicides (2,4-D and 2,4,5-T) in water-oil carrier without serious damage to jack pine when applied after August 15 (11).[14/] Trichloroacetates (TCA), applied as a post-emergent spray at the rates of 8 and 12 pounds per acre, killed 6-week-old jack pine seedlings (73).

The yield of kraft pulp per cubic foot of solid wood is considerably higher for slow-growing suppressed trees (12.11 pounds) and the lower portions of trees (11.98 pounds) than for the less dense wood portions (11.12 to 11.74 pounds) (34). In typical northern Minnesota trees summerwood forms 30 percent of the volume of the annual ring (72). In the annual ring next to the pith the tracheid length increases rapidly from the base up to 21 feet and then remains constant (72).

RACES, HYBRIDS, AND OTHER GENETIC FEATURES

Jack pine grows over a wide geographic range. It is likely, therefore, that it has developed considerable genetic diversity. A study in Minnesota has shown differences in growth, form, and insect damage among jack pines of different seed origins over its range; in general the selections moved north have made better height growth than those moved south (108). Among trees native to Minnesota, variations have been observed in cone characteristics, stem and crown form (a fastigiate form was located), apparent vigor, and apparent resistance to jack-pine budworm and pine-oak rust (103).

14/ Unpublished data, Lake States Forest Experiment Station.

Fossil cones of jack pine indicate it grew as far south as the Blue Ridge Mountains during glaciation (85). Thereafter it again migrated to the north.

There are some general indications that jack pines from the warmer parts of the natural range produce larger seeds than those from the colder portions (127). Also young seedlings of Lake States origins from higher latitudes show more pronounced winter coloration than those from lower latitudes when grown at intermediate latitudes (123).

In northwestern Canada (Alberta) the range of jack pine overlaps that of the rather similar lodgepole pine (Pinus contorta), and natural hybrids between the two species occur there (66, 84). Forms intermediate in cone, foliage, stem form, and crown habit occur along with the putative parent species (83). The same cross has also been produced artificially (93). In southern Lower Michigan this hybrid shows promise for Christmas tree purposes.[15/] First generation (F1) artificial hybrids produced turpentine in which the bi-cyclic terpenes of jack pine dominated over the simpler monocyclic terpene-phellandrene of lodgepole pine. Trees in natural hybrid swarms also tended toward a predominance of the jack pine bi-cyclic terpenes (82). Also reported is an artificial hybrid between jack pine and Scotch pine (Pinus sylvestris) (93).

Vegetative cells of ordinary jack pines, like those of all pines so far reported, contain 24 (12 pairs) chromosomes (105).

15/ Rudolph, V. J., unpublished information in letter of 9/21/56 to Director, on file at Lake States Forest Experiment Station.

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Station Paper 44 - Red pine
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Station Paper 47 - Rock elm
Station Paper 49 - Quaking aspen
Station Paper 50 - Sugar maple
Station Paper 52 - Tamarack
Station Paper 54 - American elm
Station Paper 55 - White spruce
Station Paper 59 - Slippery elm

Ensuing reports will cover the following species:

American basswood
Bigtooth aspen
Black maple
Balsam poplar
Northern white-cedar

SOME RECENT STATION PAPERS

Chemical Control of Brush and Trees in the Lake States.
Paul O. Rudolf and Richard F. Watt.
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